

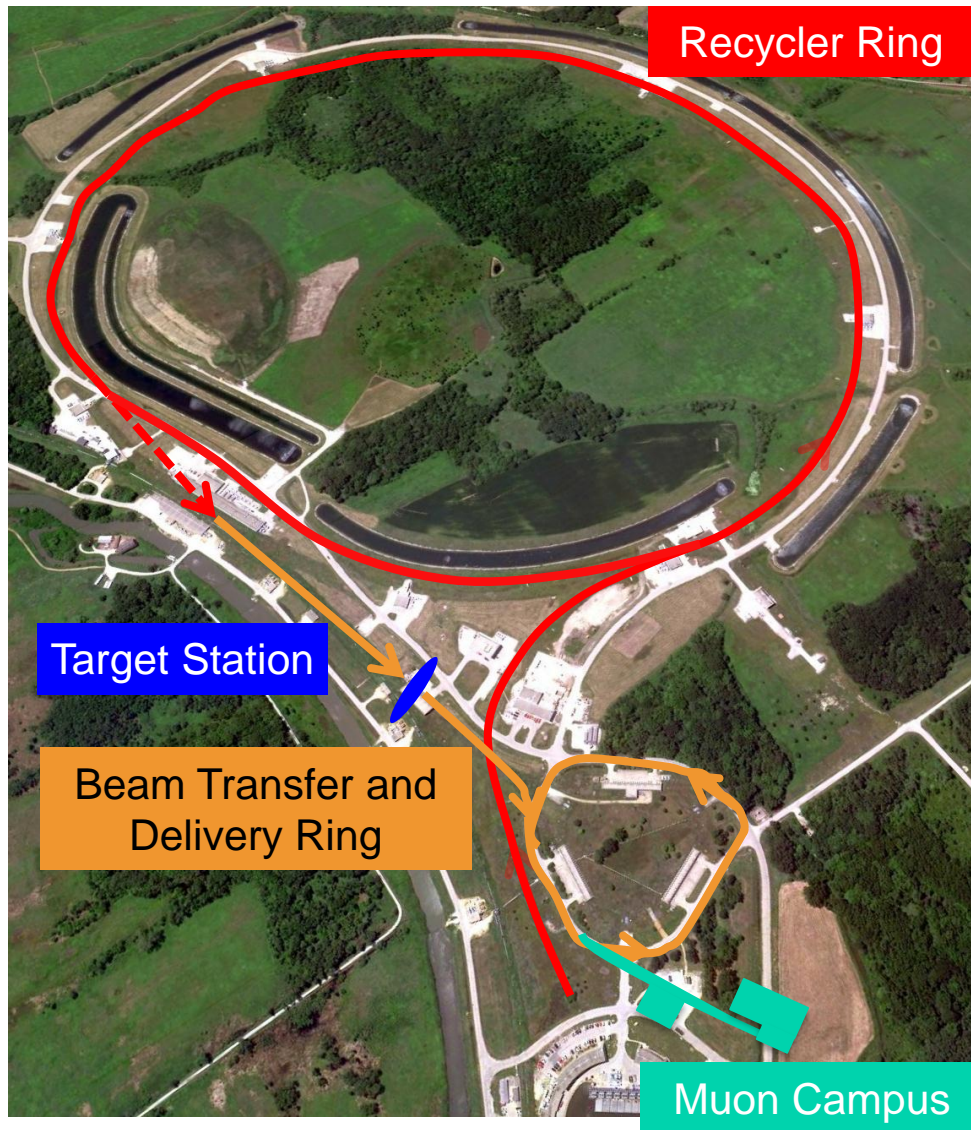
Target Yield Studies for g-2

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Studies performed by the
AD Muon Department

with help from
Instrumentation
Controls
EE Support
Mechanical Support
Operations
APC
Muons Inc

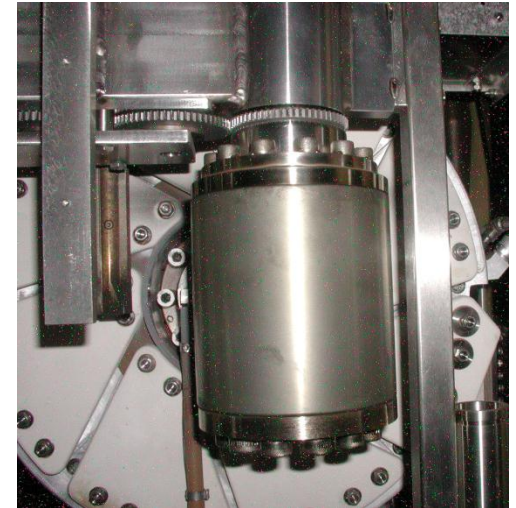
Plan for beam to g-2



- Recycler
 - 8 GeV protons from Booster
 - Re-bunched in Recycler
- Target station
 - Target
 - Focusing (lens)
 - Momentum selection
- Beamlines / Delivery Ring
 - 8 GeV protons to target
 - improve aperture and spot size on target
 - 3 GeV secondary beamline
 - improve aperture to collect muons from pion decay
 - Proton removal
 - Muons transported to g-2 ring in MC1 building

Target station

- Use existing target enclosure used for anti-proton production
- Fermilab expertise, existing spares, and radioactivity of target vault make it desirable to maintain current setup as much as possible
 - Rotating, air-cooled target
 - Lithium lens for focusing
 - Pulsed magnet for momentum selection (PMAG)
- Simulations indicate that the current setup can deliver the desired $\sim 10^{-5}$ pion/POT yield
 - Beam tests to confirm

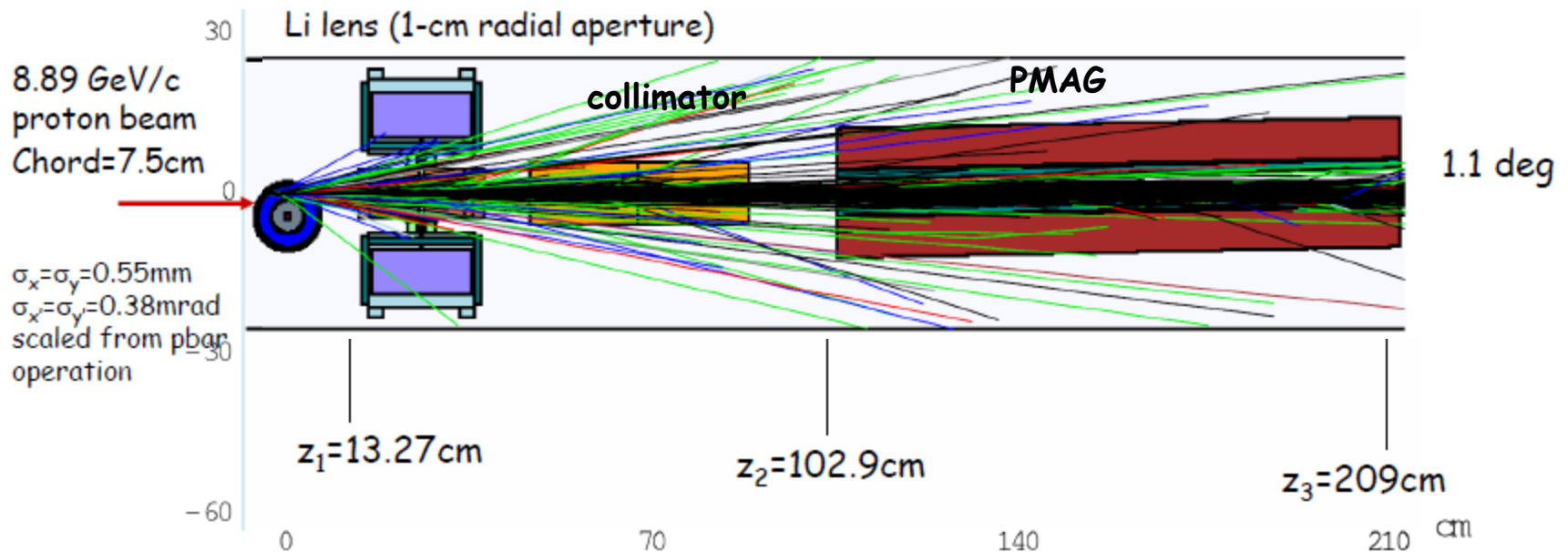


Study plan

- 120 GeV protons on target, 8.9 GeV negative secondaries
 - stacking mode
- 120 GeV protons on target, 3.1 GeV negative secondaries
 - change magnet strengths, etc, in PMAG, AP2 line, Debuncher
- 8.9 GeV protons on target, 3.1 GeV negative secondaries
 - take “reverse proton” mode beam to target
- 8.9 GeV protons on target, 3.1 GeV positive secondaries
 - change polarity of lens, PMAG, AP2 line
 - g-2 mode

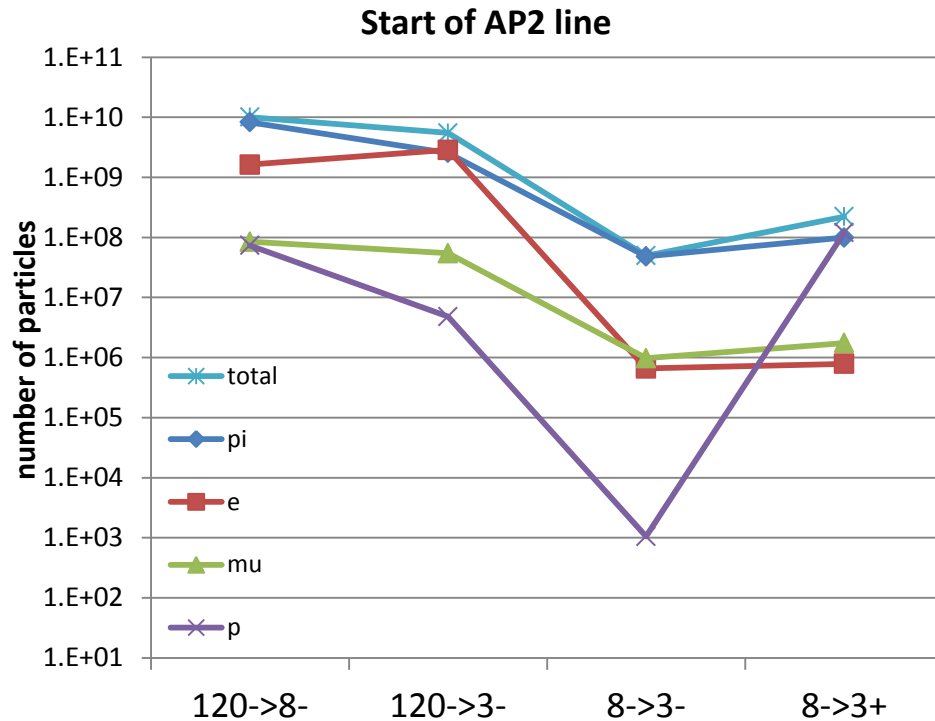
Simulation and particle tracking

- MARS simulation of target station
 - Yield per POT: $\sim 10^{-5} \pi^+$, $\sim 2\times$ as many protons, $\sim 10^{-8} \mu^+$

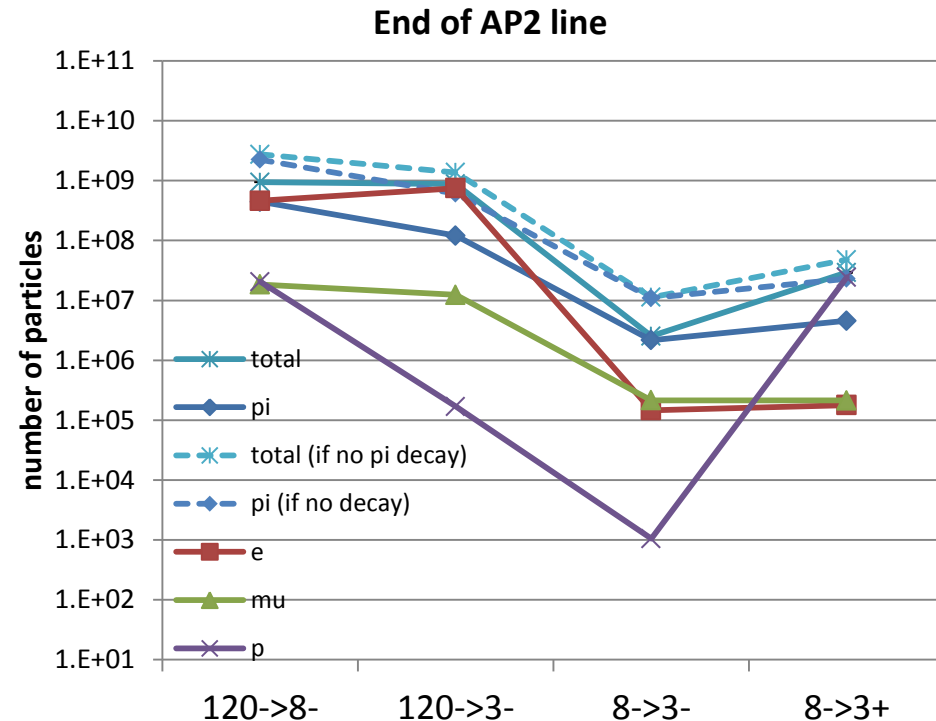


- G4beamline simulation of start of pion decay line

Expected number of particles for 1E12 protons on target (g-2 single pulse)



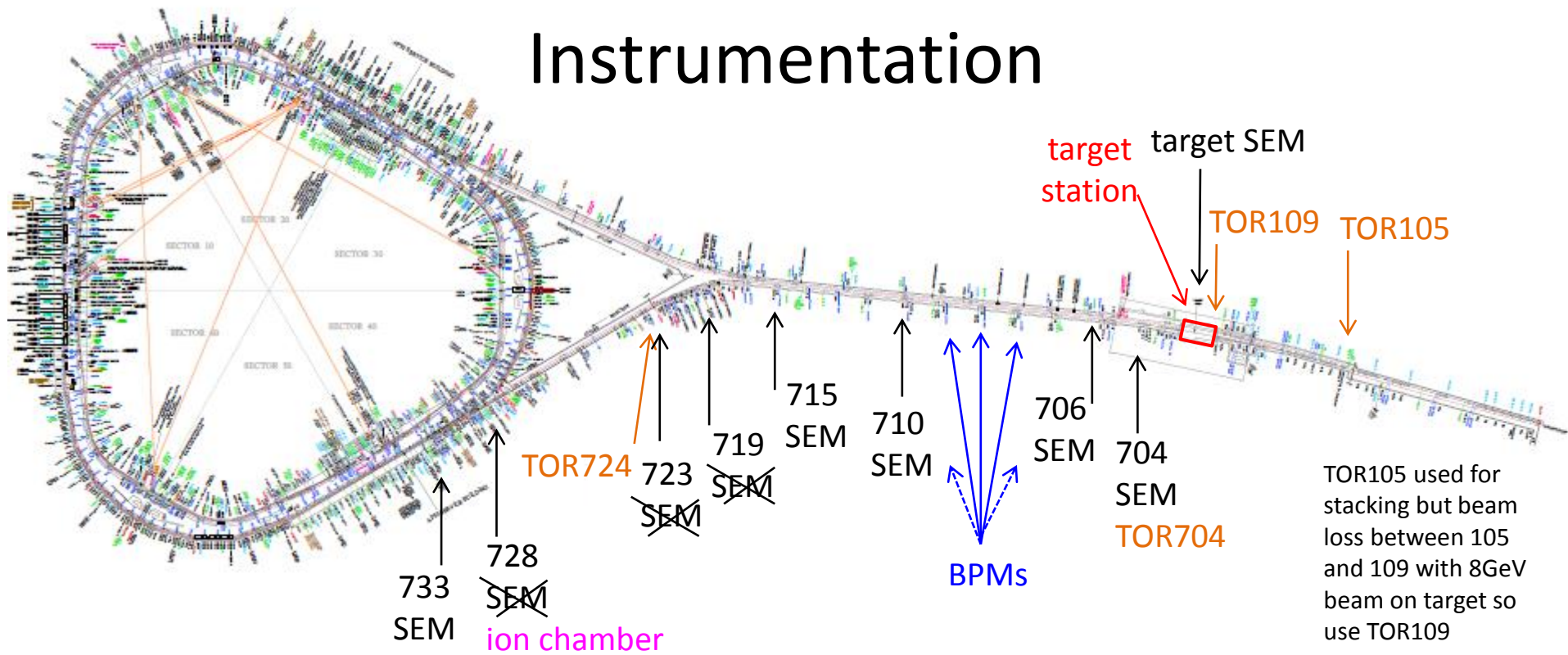
MARS and G4beamline results
 $|dp/p| < 10\%$, $\varepsilon_{x/y} < 40\pi$ mm-mrad



(simulated acceptance only)
 $|dp/p| < 2\%$, $\varepsilon_{x/y} < 35\pi$ mm-mrad
 plus pion decay

Larger spot size for 8 GeV beam on target taken into account

Instrumentation

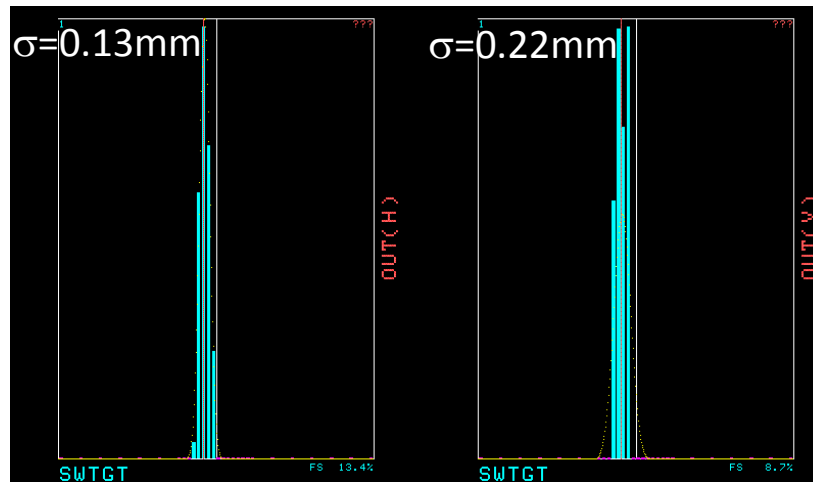


mode	ion chamber	SEM 733	SEM 715	SEM 710	SEM 706	SEM 704	BPMs	TOR 724	TOR 704
120→8-	not installed	✓	✓	✓	✓	✓	✓	✓	✓ scope trace
120→3-	✓	✓	✓	✓	✓	✓	✓	✓	✓ scope trace
8→3-	✓	preamp removed as test	✓ high-gain preamp	no high-gain preamp	✓ high-gain preamp	high-gain preamp bad	on spectrum analyzer		✓ scope trace
8→3+	✓	✓ high-gain preamp	✓ high-gain preamp	no high-gain preamp	✓ high-gain preamp	high-gain preamp bad	✓ signals up to 705		✓ scope trace

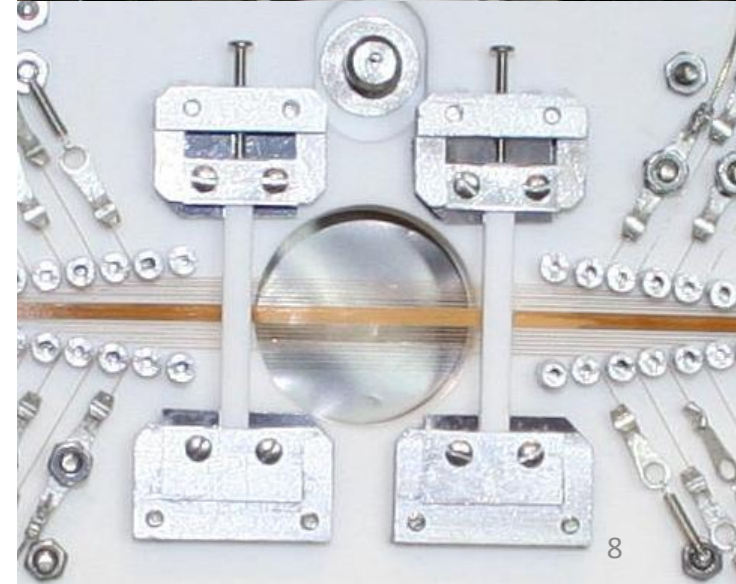
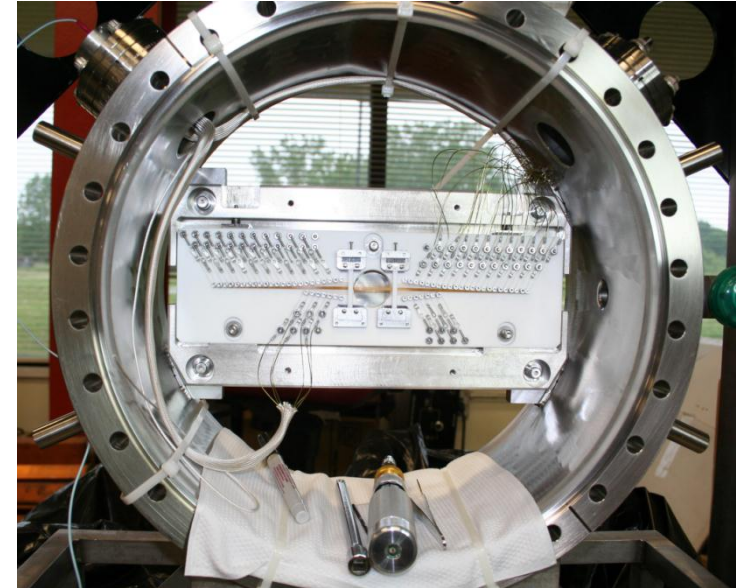
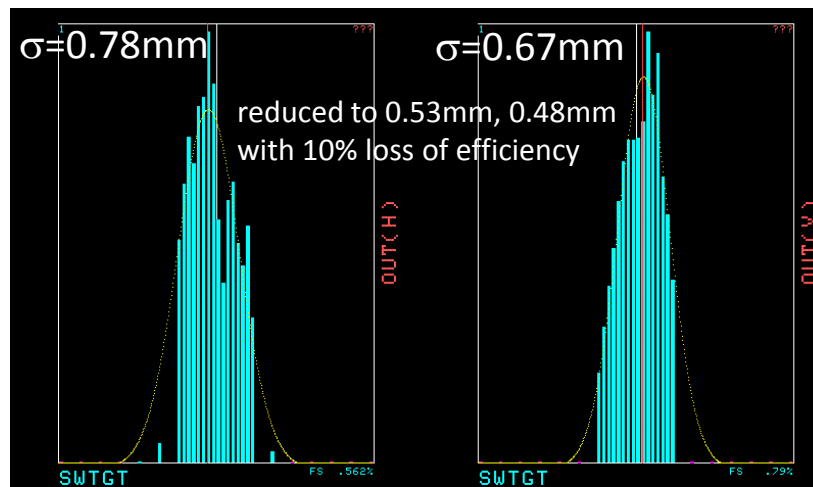
Target Secondary Emission Monitor

- Target SEM shows spot size is bigger for 8 GeV beam on target than 120 GeV, as expected

120 GeV

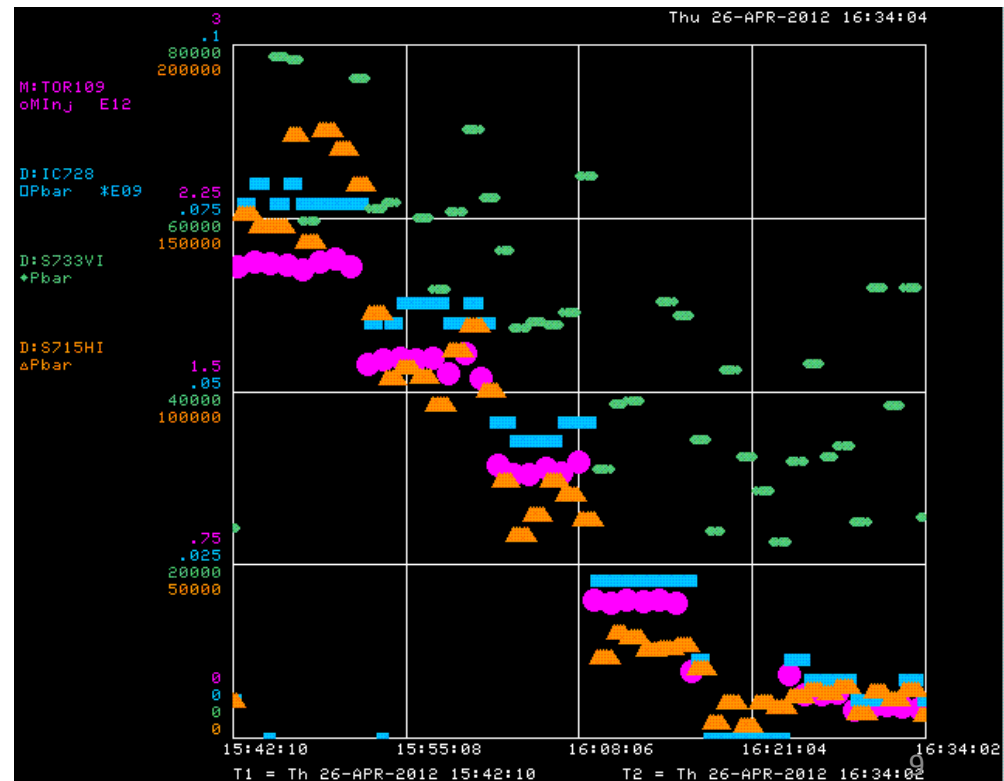
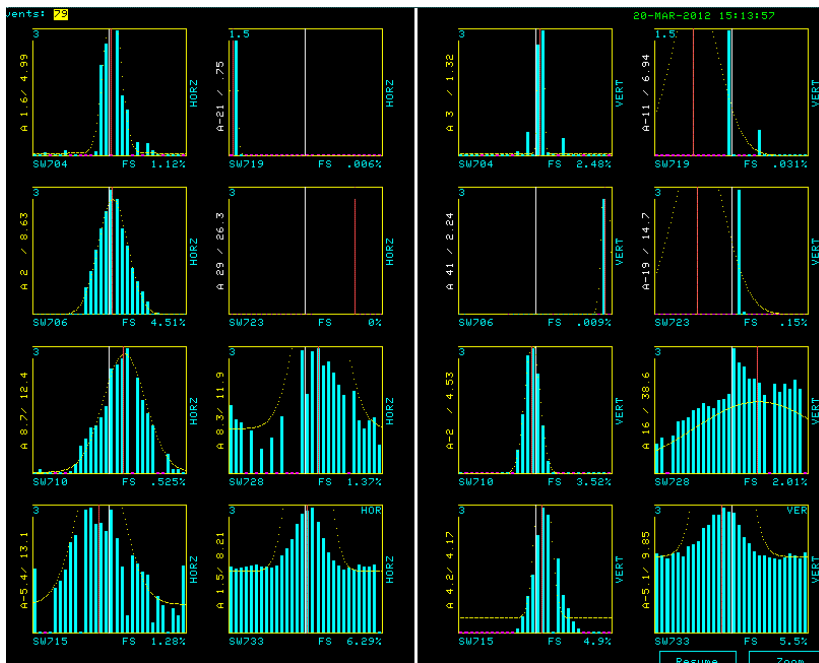


8 GeV



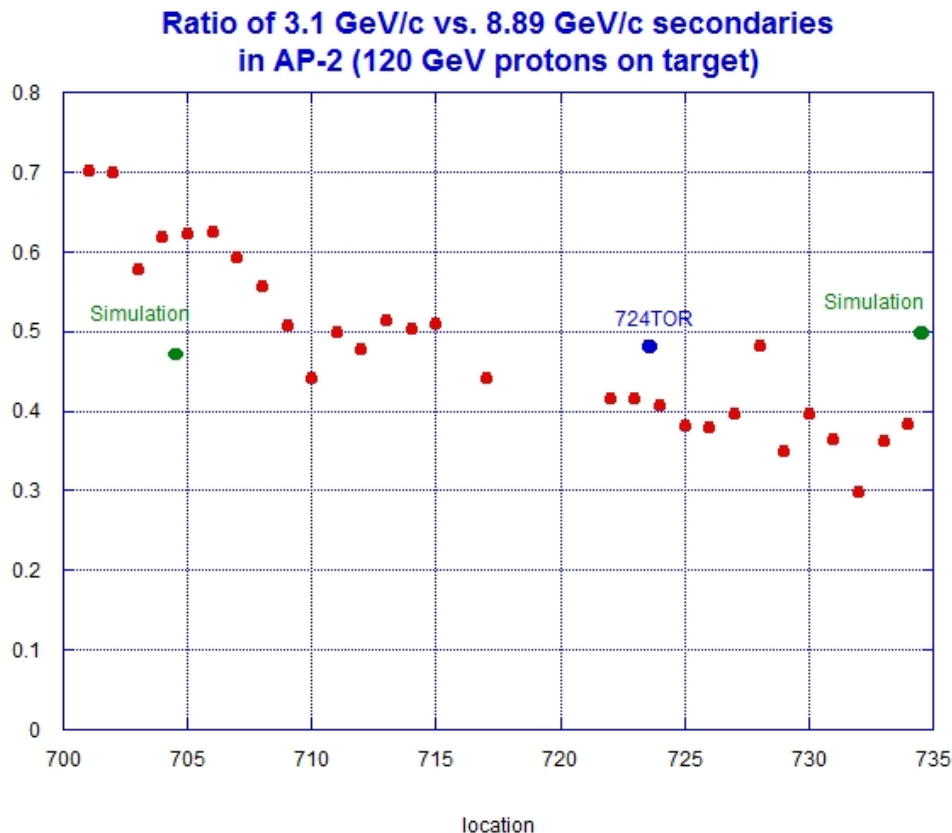
AP2 line SEMs

- Went through many iterations of gain, integration time, low- and high-gain preamps, methods of background subtraction and prescriptions for calculating intensity
- Learned a lot, but not so easy to compare intensity from day to day (mode to mode)
- Intensities do track beam on target



Beam Position Monitors

- Can compare $120 \rightarrow 8^-$ and $120 \rightarrow 3^-$
- $8 \rightarrow 3^-$ signals only visible using a spectrum analyzer
- $8 \rightarrow 3^+$ signals visible only at the beginning of the AP2 line and after reducing signal attenuation



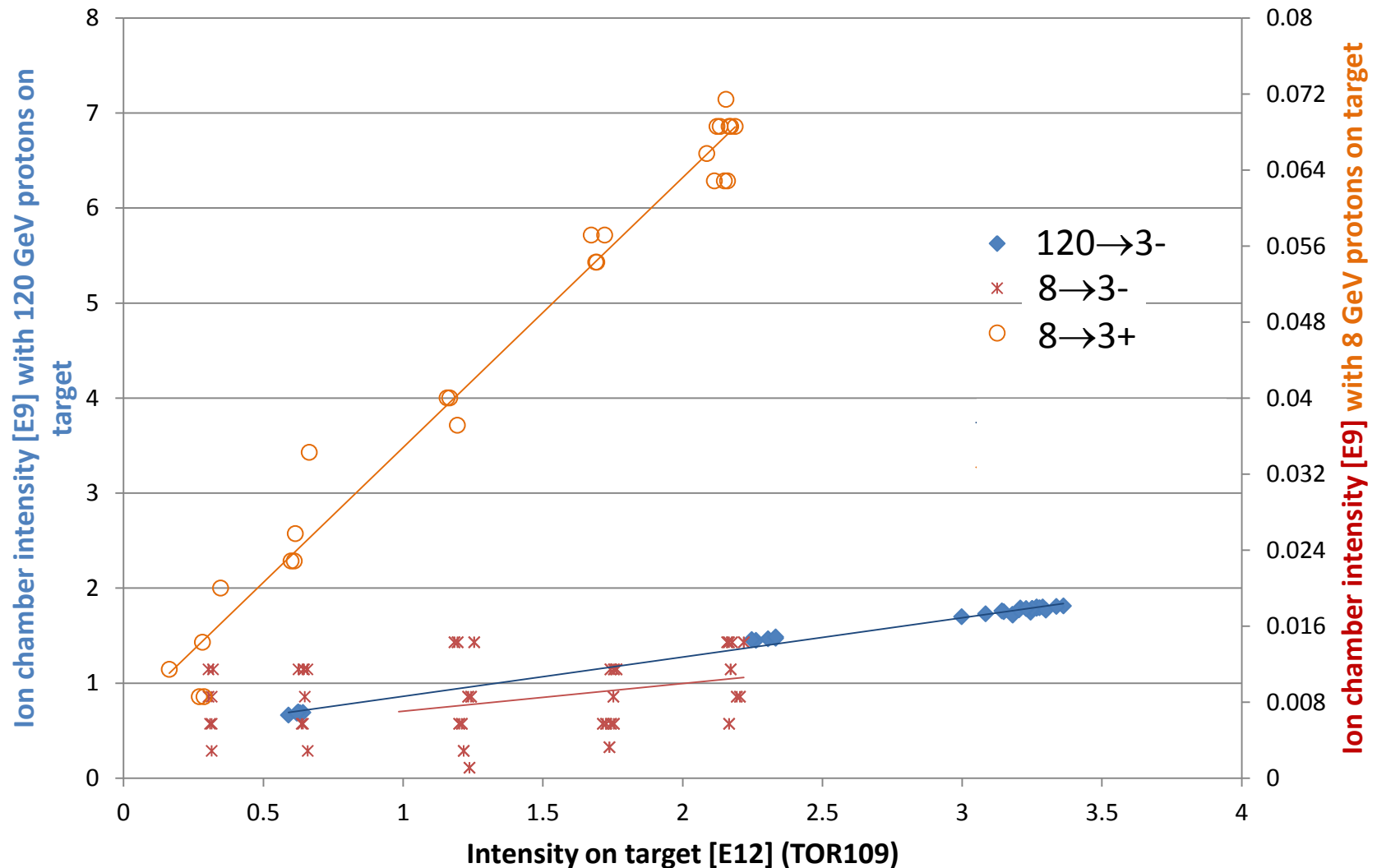
$120 \rightarrow 3^-$ to $8 \rightarrow 3^+$ comparison
still in progress

Ion chamber

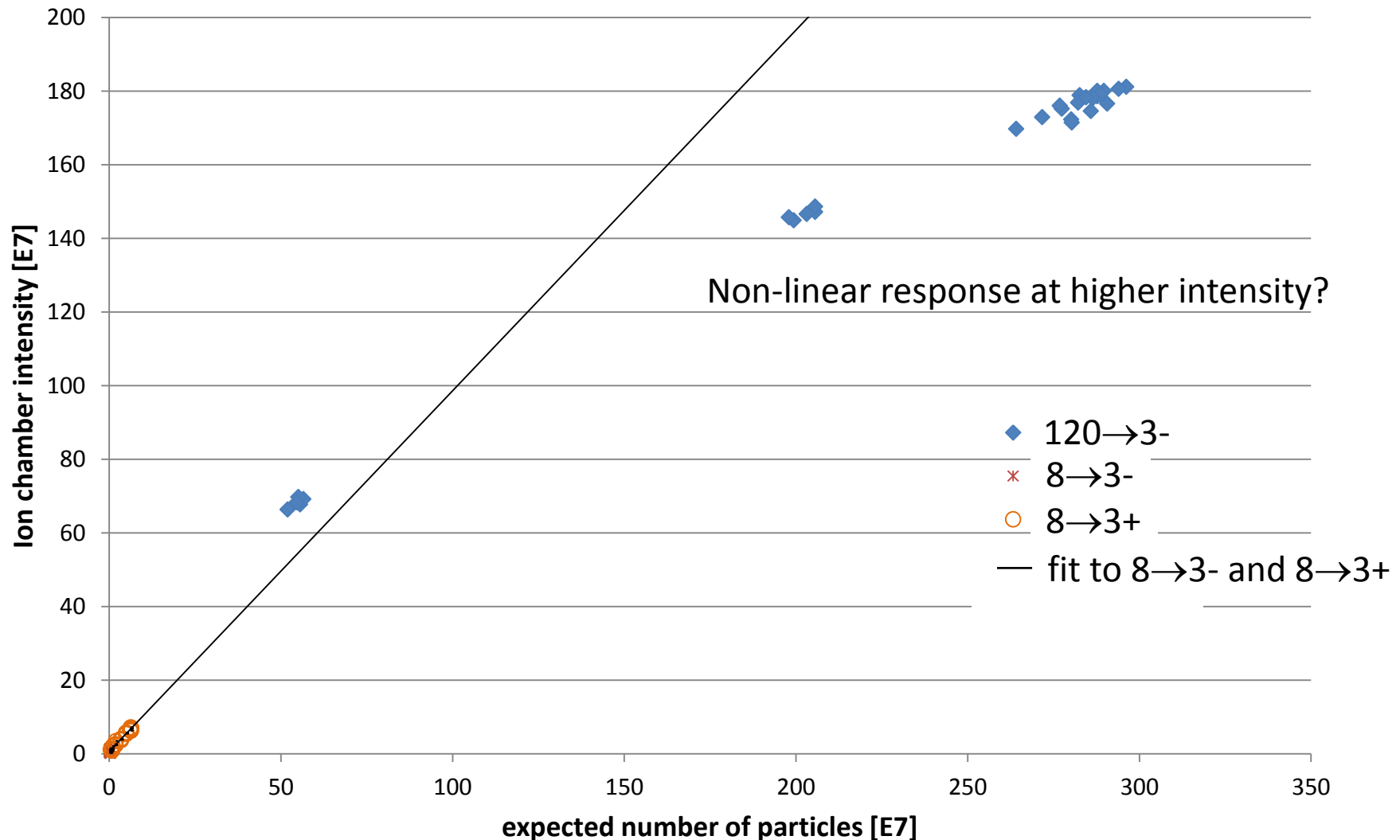
- Removed ~10 years ago
- We reinstalled vacuum windows, hooked it up, and ran
- Electronics were still hooked up, though both HV supply and readout digitizer were bad and had to be replaced
- Using Argon gas
- Calibrated???
- Should be able to look at ratio between different modes



Ion chamber readout vs intensity on target

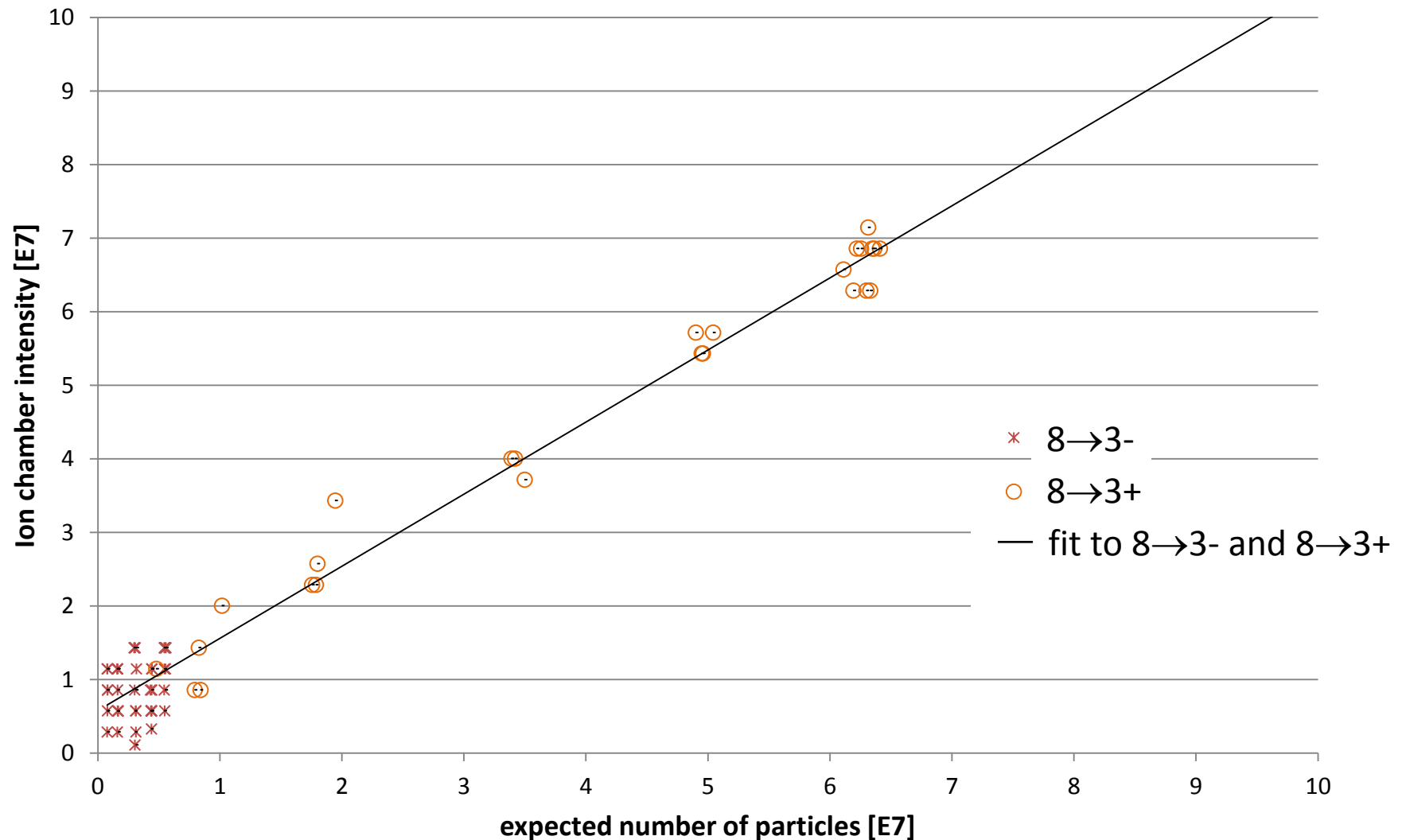


Ion chamber intensity vs expected number of particles (from simulation based on intensity on target)



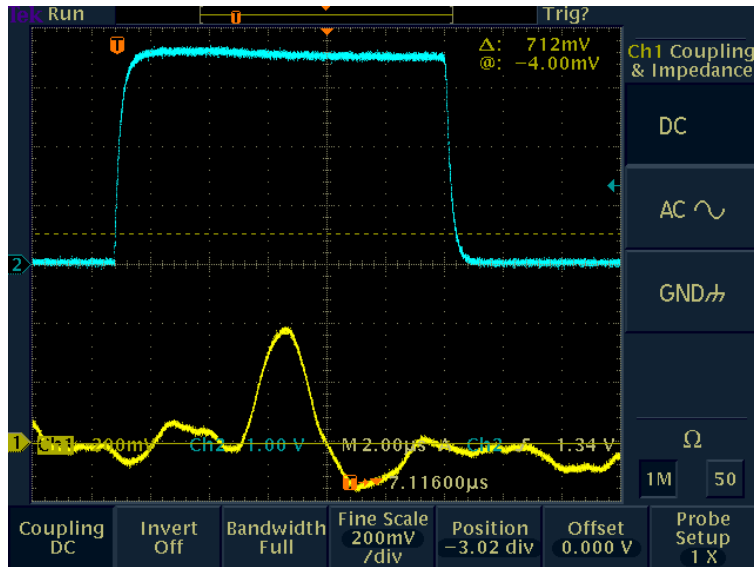
Results don't quite agree with simulation?
(Remember we didn't do a full simulation of the AP2 line)

Close up of data with 8GeV beam on target

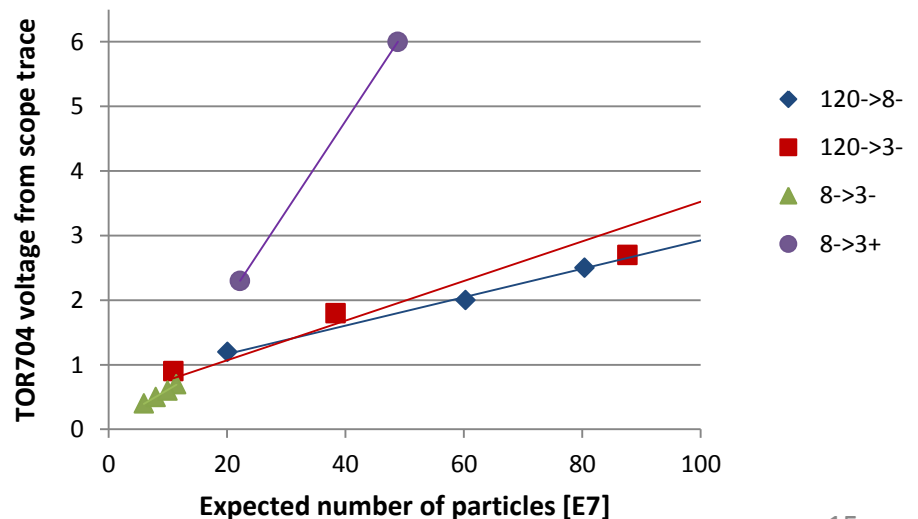
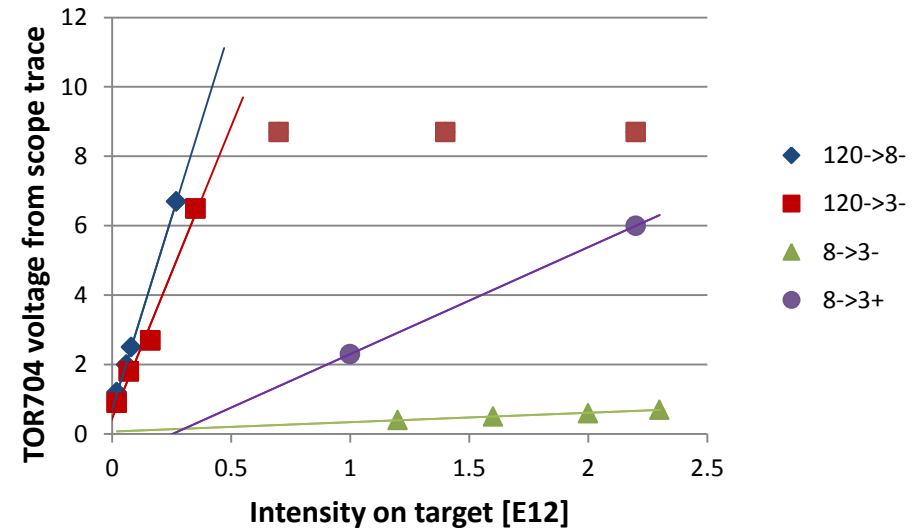


Toroids

- Signal on TOR724 (end of AP2 line) only for 120 GeV beam on target
- TOR704 (start of AP2 line):
got scope traces of voltage
which can be compared
from mode to mode

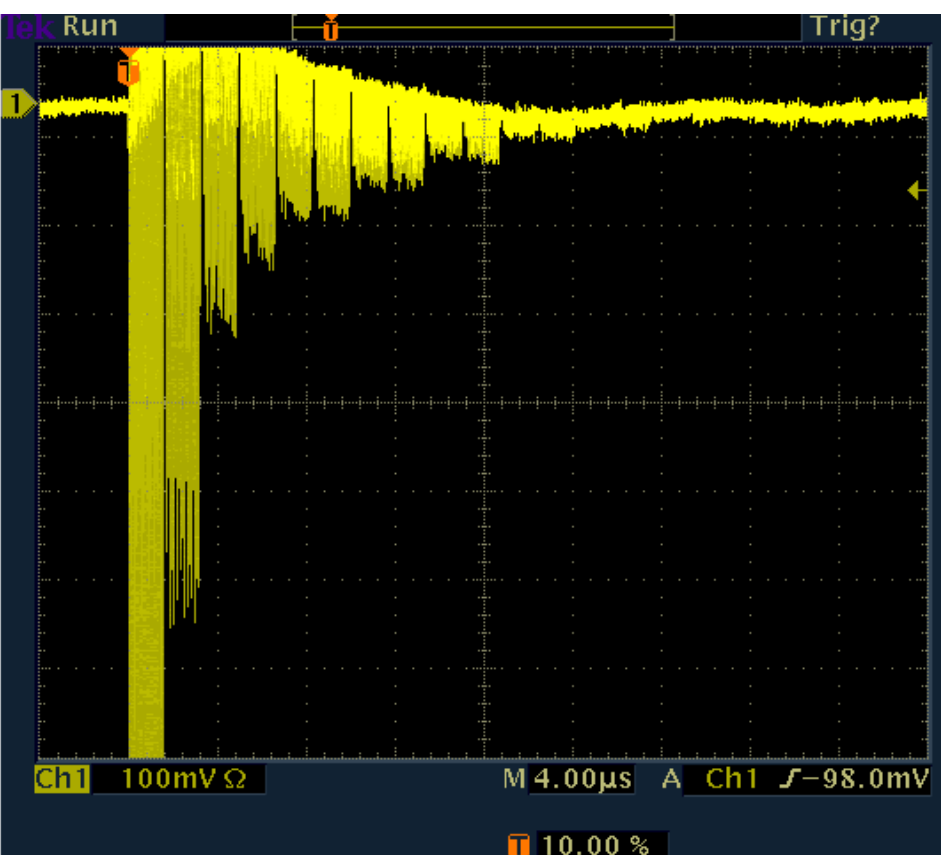


- Careful analysis taking noise into account shows similar discrepancy for $8 \rightarrow 3+$

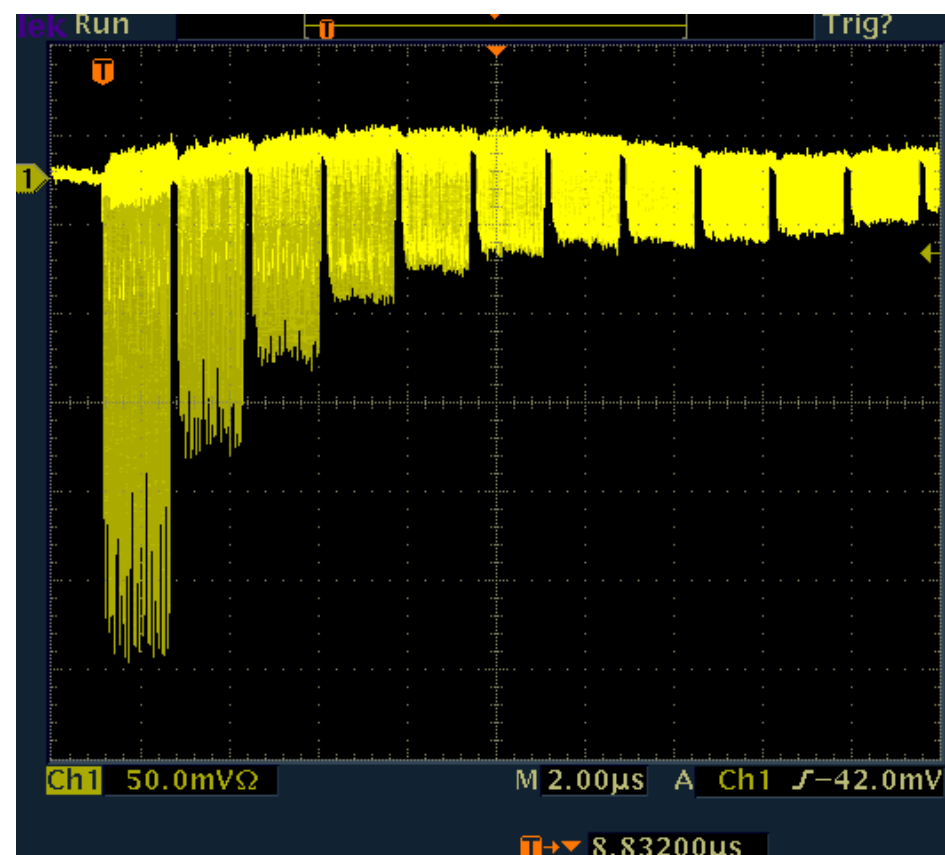


3 GeV beam (120→3-) circulating in Debuncher

(8→3- intensity too small to see and did not switch polarity of Debuncher to look at 8→3+)

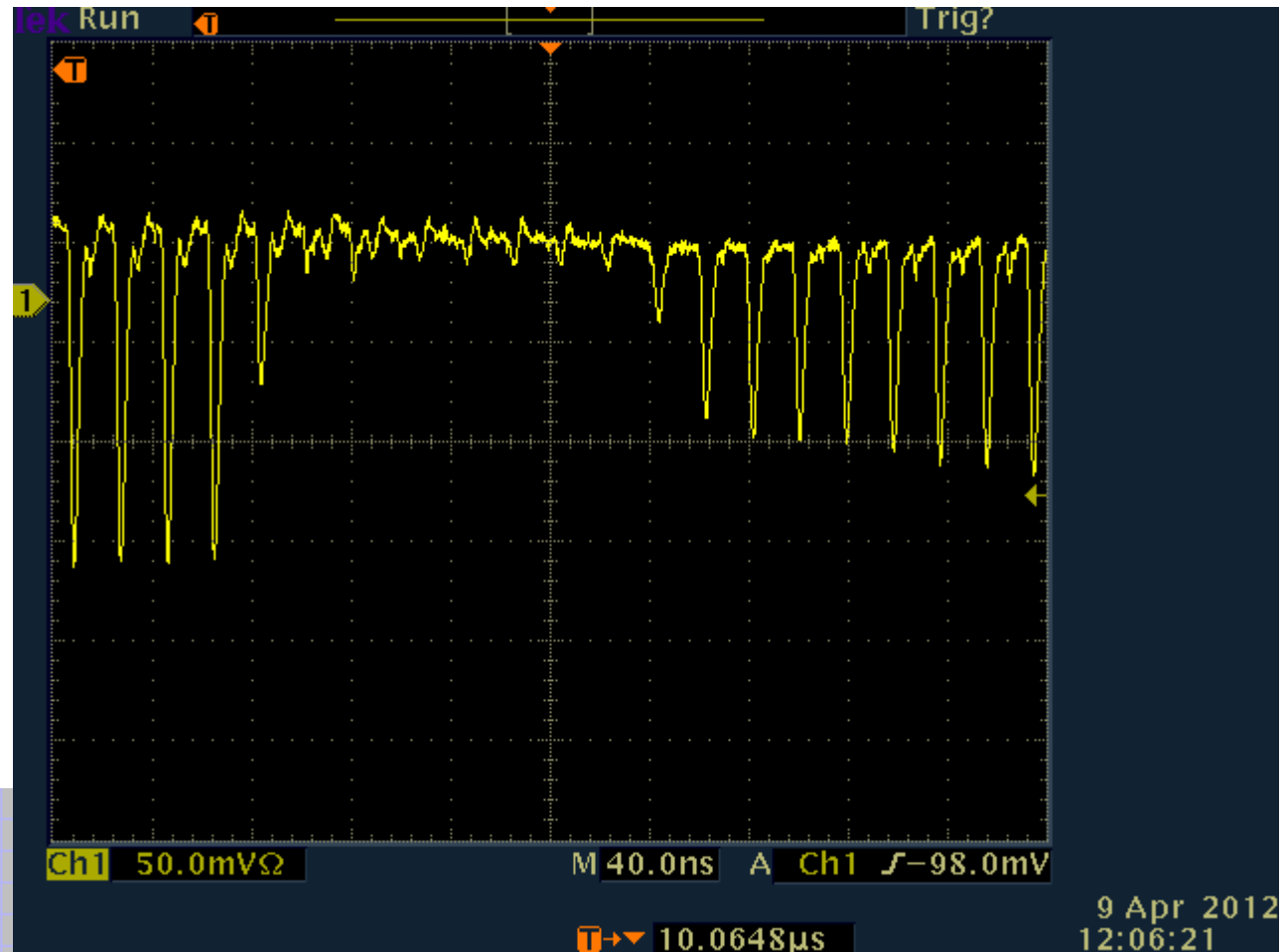


Debuncher gap monitor showing the first 10+ turns of 8 GeV secondaries, first turn off scale

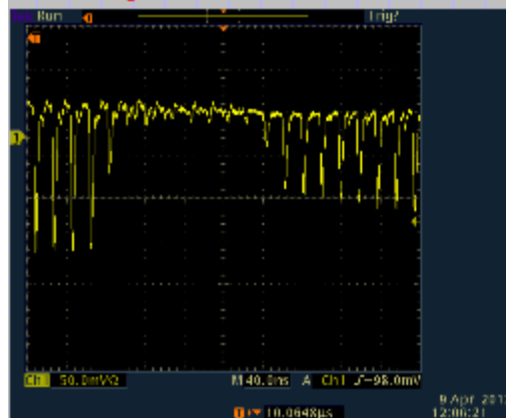


Debuncher gap monitor showing first 11 turns of 3 GeV secondaries

Separation of pbars from lighter particles in Debuncher (3 GeV)



Mon Apr 9 12:15:34-



This is the end of the 6th turn and beginning of the 7th turn. If you ignore the ringing doublet in the gap between the bunch trains, you can see the three pbar bunches that have slipped past the pions and muons. On the next (7th) turn, you can see the area between the first several bunches are empty, but the pbars then appear between latter bunches.

Conclusions

- Toroid at beginning of AP2 line shows expected scaling from $120 \rightarrow 8^- / 120 \rightarrow 3^-$
- Ion chamber at end of AP2 line shows order-of-magnitude agreement with predictions: 10^9 particles for $120 \rightarrow 3^-$ and 10^7 particles for $8 \rightarrow 3^-$ and $8 \rightarrow 3^+$ per 10^{12} protons on target
- Have circulated 3GeV (negative) beam in the Debuncher